IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, May 2025
Impact Factor: 7.67

Blood Supply Chain Monitoring System using ICP Blockchain

Darshan Hegde[1], Om Hawaldar[2], Prajwal S G[3], Sanket Mallapur[4], Seema S Reshmi[5]
4th year, Department of ISE [1-4]
Assistant Professor, Department of ISE[5]
Global Academy of Technology, Bengaluru, India

Abstract: *The safe and transparent management of donated blood is a critical aspect of modern healthcare infrastructure. However, traditional centralized systems often suffer from issues like lack of traceability, risk of data tampering, and the proliferation of unauthorized blood banks, leading to serious health hazards. In this project, we present the* ***Blood Supply Chain Monitoring System using ICP Blockchain****, a decentralized application (DApp) designed to monitor the complete journey of blood units — from donation to transfusion or disposal. Our platform registers authorized blood banks, hospitals, and patients, enabling a designated staff member to record and track the movement of each blood packet, uniquely identified with a traceable ID. Built on the Internet Computer (IC) blockchain, the system ensures immutability, public auditability, and cost-efficiency, addressing the alarming issues of fake blood supply and illegal market practices. By leveraging the transparency of Web3 technologies, our solution provides a global, tamper-proof, and highly scalable blood management system that could significantly reduce the risk of disease transmission from contaminated blood, enhance public trust, and help eradicate unauthorized blood banks. Comparative insights drawn from recent blockchain-based healthcare systems further validate the relevance and urgency of our proposed solution.*

Keywords: Blood Supply Chain, Blockchain Technology, Internet Computer Protocol (ICP), Blood Donation Monitoring, Decentralized Application (DApp), Blood Bank Authorization, Blood Inventory Management, Web3 Healthcare Solutions, Data Immutability, Blood Traceability

I. INTRODUCTION

Blood is a vital component in modern healthcare, essential for surgeries, trauma care, cancer treatment, and various chronic illnesses. Despite its critical importance, the blood donation and supply chain in many countries faces persistent challenges such as poor traceability, illegal blood trade, unauthorized blood banks, and the risk of disease transmission through contaminated blood. Reports reveal that in India alone, approximately 600 out of 1,000 blood banks operate without proper authorization, contributing to an illegal blood market valued at over 300 crores INR. Furthermore, around 0.14% of transfused blood is contaminated, resulting in an alarming number of infections annually, including diseases such as HIV and hepatitis. Traditional centralized systems for blood management suffer from vulnerabilities including single points of failure, lack of transparency, data manipulation, and limited public visibility. These systemic issues compromise the safety and integrity of the blood supply chain. To address these concerns, blockchain technology has emerged as a transformative solution, offering features like decentralization, immutability, traceability, and transparency.

In this project, we propose the Blood Supply Chain Monitoring System using ICP Blockchain — a decentralized application (DApp) deployed on the Internet Computer Protocol (ICP). Unlike conventional systems, our platform enables designated personnel from authorized blood banks and hospitals to register donors, patients, and blood banks, monitor blood movement in real time, and record every transaction on a tamper-proof blockchain ledger. Each donated blood unit is assigned a unique identifier, ensuring complete traceability from donation to utilization or disposal. By utilizing ICP blockchain, our system achieves low-cost deployment, high scalability, and global accessibility, embodying the principles of Web3 technology. In addition to securing the supply chain, our platform helps eliminate unauthorized blood banks by allowing only registered entities to participate, thereby safeguarding public health and restoring trust in blood donation practices.

The subsequent sections of this paper present a comprehensive literature survey based on recent blockchain-based healthcare management solutions, the detailed architecture and working of the proposed system, and an evaluation of its potential impact on improving blood donation traceability and security. Blood is a fundamental and life-sustaining fluid that plays a critical role in saving lives during surgeries, trauma care, cancer therapies, and treatment of chronic diseases. The efficiency, reliability, and safety of the blood donation and supply process are therefore paramount to healthcare systems worldwide. Despite numerous advancements in medicine and technology, the blood supply chain remains vulnerable to several challenges, including inadequate traceability, presence of unauthorized blood banks, counterfeit blood supplies, and improper storage or handling of blood units. These inefficiencies not only result in resource wastage but also pose severe risks to public health, with instances of patients contracting life-threatening infections such as HIV and hepatitis from contaminated blood.

In India, alarming statistics highlight the gravity of the situation. Out of an estimated 1,000 blood banks operating across the country, nearly 600 are unauthorized, contributing significantly to a black-market blood trade worth over ₹300 crores annually. Moreover, approximately 0.14% of blood units are contaminated, leading to around 17,000 infected units per year, and impacting nearly 1,500 individuals annually through transfusion-transmitted infections. Such figures underline an urgent need for a robust, transparent, and tamper-proof blood supply management system that can restore trust and integrity in the donation process.

Traditional blood management systems, predominantly centralized, are often plagued by issues like a single point of failure, susceptibility to data manipulation, lack of transparency, and limited accessibility for public auditing. In such centralized frameworks, a breach or corruption at any single node can disrupt the entire network, resulting in the loss or distortion of critical medical data. Furthermore, patients and hospitals are left with no reliable way to verify the authenticity and quality of the blood they receive, putting lives at unnecessary risk.

To address these pressing challenges, blockchain technology emerges as a revolutionary solution. Known for its decentralized, immutable, and transparent nature, blockchain offers an ideal framework to manage sensitive healthcare operations. By recording each transaction or event on a distributed ledger that is visible to authorized participants but immutable to tampering, blockchain ensures a new standard of trust, accountability, and traceability.

In this context, we propose the Blood Supply Chain Monitoring System using ICP Blockchain, a decentralized application (DApp) built on the Internet Computer Protocol (ICP) blockchain platform. Our system is designed to monitor the complete lifecycle of donated blood — from donation, testing, storage, supply, to transfusion or safe disposal. Each unit of blood is assigned a unique traceable ID, and the movement of every unit is recorded through designated administrative users at blood banks and hospitals. This structure prevents unauthorized blood banks from participating, enhances inventory management through real-time updates, and enables public verification without compromising data integrity or privacy.

Leveraging the unique capabilities of ICP blockchain, such as low transaction costs, high scalability, and seamless web integration, our platform embodies the next generation of healthcare infrastructure. Additionally, by fully deploying the system on ICP, we achieve the benefits of Web3 — including global accessibility, decentralized ownership, and long-term sustainability.

The remainder of this paper is organized as follows: Section II presents a detailed literature survey of existing blockchain-based solutions in healthcare management; Section III describes the architecture and workflow of our proposed system; Section IV discusses the key features and expected impact of the platform; and Section V concludes the paper with future directions for scaling and enhancing blood donation traceability worldwide.

Literature review: The traditional management of blood and organ donations has been historically plagued by issues such as lack of transparency, traceability failures, data tampering, and the dominance of centralized control systems. To address these challenges, several researchers have proposed blockchain-based solutions to ensure data integrity, accountability, and efficient management of sensitive healthcare resources like blood, organs, and allografts.

Hawashin et al. proposed a private Ethereum blockchain-based blood donation management system aimed at solving major issues like traceability, immutability, auditability, and security in the blood donation supply chain. Their

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, May 2025
Impact Factor: 7.67

architecture involved decentralized storage using IPFS for handling large non-critical data and developed smart contracts to automate donation processes. The solution notably ensured transparency and minimized blood wastage. However, the reliance on private Ethereum and IPFS introduced concerns regarding transaction costs and occasional scalability issues when expanded to large-scale deployments. Despite its robustness, their system was primarily limited to blood component tracking without extensive real-time request management or large-scale decentralized deployment.

Expanding blockchain applications to broader healthcare needs, Hawashin et al. also proposed a blockchain-based management system for organ donation and transplantation. This work focused on addressing the legal, ethical, and clinical challenges faced during donor-recipient matching, organ removal, delivery, and transplantation. Using private Ethereum smart contracts, the system ensured decentralized registration, auto-matching of donors and recipients, and provided secure logging of events during transplantation stages. The solution introduced auto-matching algorithms and focused heavily on maintaining patient data privacy. However, similar to the blood management system, it was dependent on private Ethereum networks, which while improving privacy, could pose cost inefficiencies and deployment restrictions at a global public level.

Further extending the application of blockchain in sensitive transplant domains, Haq et al. presented Transchain, an Ethereum blockchain-based management system for allografts aimed at enhancing data provenance. Their system introduced gas-efficient smart contracts and cost-effective architectures to manage donation, transportation, and transplantation processes securely. Detailed algorithms were developed for patient registration, donor matching, surgery logging, and organ delivery using a multi-phase approach. While Transchain demonstrated lower operational costs and better throughput compared to previous systems, it also highlighted challenges around large data handling with IPFS and some complexities related to smart contract management for real-time high-frequency transactions.

Across all three works, a common observation emerges: while blockchain solutions significantly improve traceability, accountability, and data security, challenges like transaction costs, scaling to large populations, and handling decentralized public access at minimal infrastructure costs remain only partially addressed.

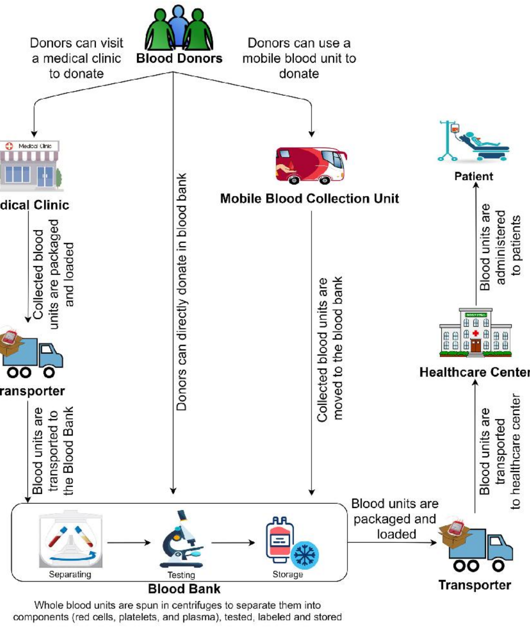
To overcome these limitations, the Blood Supply Chain Monitoring System using ICP Blockchain is proposed in this project. Unlike traditional Ethereum-based solutions, the Internet Computer Protocol (ICP) offers a cost-effective, highly scalable, and globally decentralized platform for deploying blockchain applications. By assigning unique IDs to every blood unit, ensuring complete lifecycle tracking from donation to transfusion or disposal, and authorizing only verified blood banks and hospitals to participate, our system directly addresses issues like unauthorized blood supply, fake blood banks, and bloodborne infection risks. Additionally, ICP's direct integration with the web and its minimal storage costs make it a promising next-generation platform to truly scale blood monitoring systems globally without sacrificing decentralization or transparency.

Thus, this project builds upon and advances the foundation laid by previous blockchain-based healthcare solutions by choosing a more scalable blockchain platform (ICP), introducing real-time blood inventory request management, and strict authorization controls to combat illegal blood markets and enhance patient safety worldwide.

In recent years, the healthcare industry has increasingly explored blockchain technology as a promising tool to solve fundamental problems related to data security, provenance, traceability, and decentralized management. The critical need for transparent and tamper-proof supply chains in sensitive domains like blood donation and organ transplantation has driven significant research interest. This section reviews notable contributions in the field and analyzes their relevance to the design of our proposed Blood Supply Chain Monitoring System using ICP Blockchain.

Hawashin et al. proposed a private Ethereum blockchain-based blood donation management system that focuses on decentralization, transparency, and traceability of blood supply chains. Their architecture utilized smart contracts to automate blood donation processes and integrated IPFS (InterPlanetary File System) for decentralized off-chain storage of large non-critical data such as blood unit reports. Their system successfully addressed issues like blood traceability and auditability while maintaining donor data privacy. However, the solution's dependency on private Ethereum networks introduced certain limitations, particularly regarding scalability, operational costs (gas fees), and integration complexities when expanding across diverse and widespread healthcare institutions.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, May 2025
Impact Factor: 7.67



Building upon the foundation of decentralized healthcare management, Hawashin et al. further developed a blockchain-based organ donation and transplantation system. This work tackled the multi-staged process of organ registration, donor-recipient matching, organ procurement, and transplantation logistics, integrating smart contracts to automate and secure each step. The proposed system introduced auto-matching algorithms to prioritize matches based on medical parameters and ethical considerations, thereby reducing human bias. Although this solution strengthened process integrity and transparency in organ transplantation workflows, challenges such as the cost of running private blockchain infrastructures and potential bottlenecks during high-volume operations remained critical concerns.

Similarly, Haq et al. introduced Transchain, a blockchain-based management system for allografts with an emphasis on enhancing data provenance. Their work addressed cost-effectiveness more directly by proposing gas-efficient smart contracts and offering a detailed multi-layered architecture separating actors (users), front-end interfaces, and blockchain back-ends. Transchain demonstrated that blockchain systems could be designed to achieve high security, traceability, and transaction throughput without exorbitant operational costs. Nevertheless, while focusing on medical data provenance and organ transplantation, Transchain also highlighted the persistent challenge of managing large-scale decentralized systems without encountering storage, retrieval, and privacy concerns — especially when IPFS is involved for off-chain storage.

Recognizing these limitations, our project proposes a next-generation solution — the Blood Supply Chain Monitoring System using ICP Blockchain. Unlike previous works that utilized Ethereum-based frameworks, our system leverages the Internet Computer Protocol (ICP) blockchain, offering significant advantages in scalability, cost-efficiency, and web-native integration. ICP's architecture allows smart contracts (called canisters) to run at internet speed and scale, without incurring traditional gas fees, making it highly suitable for public healthcare applications.

Moreover, while earlier works primarily targeted traceability within a closed network, our solution aims for a globally accessible, publicly verifiable, yet highly secure blood monitoring platform. We ensure that only authorized blood banks, hospitals, and administrators can interact with the system, thereby reducing the risks posed by unauthorized or fake blood supply centers, which are a major issue in regions like India.

II. METHODOLOGY

System Overview: The Blood Supply Chain Monitoring System using ICP Blockchain is a decentralized application (DApp) built to monitor, record, and manage the journey of blood units from the point of donation to either transfusion

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, May 2025
Impact Factor: 7.67

to patients or safe disposal. The system ensures transparency, traceability, and security at every stage of the blood supply chain while addressing issues related to unauthorized blood banks, fake donations, and contaminated blood.

Unlike public blood donation platforms that allow direct access to end-users, this system restricts access to authorized personnel — individuals representing verified blood banks and hospitals. The entire lifecycle of each blood unit is monitored through a series of blockchain transactions, recorded immutably on the Internet Computer Protocol (ICP) network, ensuring public verifiability without compromising privacy.

Through a combination of smart contracts (ICP canisters), role-based access control, and unique blood unit IDs, the system provides a complete decentralized infrastructure for managing blood supply chains across institutions and geographies.

System Objectives: The key objectives of the proposed system are:

- **Enhance Blood Traceability:** Track every movement of blood units through a publicly auditable and tamper-proof blockchain ledger.
- **Eliminate Unauthorized Blood Banks:** Only registered and verified institutions can participate.
- **Promote Transparency and Trust:** Allow stakeholders to verify blood origins and movement history.
- **Reduce Centralized Failures:** Deploy the system in a fully decentralized environment using the ICP blockchain.
- **Major Modules and Functionalities:** The system architecture is divided into distinct modules, each responsible for specific functionalities:

Donor Management Module

- **Registration:** New donors are registered by blood bank personnel with unique identifiers and necessary verification (e.g., age, medical history, blood type).
- **Blood Unit Mapping:** For every donation, a unique **Blood Unit ID** is generated, which is digitally linked to the donor profile.
- **Historical Data Access:** Blood banks can access the donation history of each donor for traceability and auditing purposes.

Patient Management Module

- **Patient Registration:** Hospitals register patients who require blood transfusion. Critical information like blood group, hospital location, and urgency status are recorded.
- **Request Generation:** Patients' blood needs generate formal blood requests submitted to nearby registered blood banks.

Blood Bank Authorization Module

- **Verification Mechanism:** New blood banks must undergo an approval process through administrative verification before they can participate.
- **Dynamic Authorization:** In case of regulatory violations, blood banks can be deauthorized or blacklisted from the system.
- **Inventory Setup:** Verified blood banks maintain their real-time blood inventory categorized by blood type and quantity.

Blood Inventory Management Module

Inventory Updates: Each blood bank’s inventory is automatically updated upon:

- New donations (inventory increase),
- Blood supply to patients (inventory decrease),
- Disposal of expired units (inventory adjustment).

Low Inventory Alerts: The system sends warnings when blood bank inventory levels fall below predefined

Blood Request and Fulfillment Module

- **Request Lifecycle:** Blood requests placed by hospitals move through various states:
- **Pending:** Awaiting action from blood bank administrators.
- **Fulfilled:** Blood supplied and acknowledged.
- **Rejected:** Due to unavailability or mismatch.
- **Real-Time Notifications:** Blood bank admins receive real-time notifications for new requests.
- **Auto-Update:** Every request fulfillment or rejection triggers automatic inventory updates to maintain accuracy.

Blockchain Design and Integration

Internet Computer Blockchain Selection

The system leverages the **Internet Computer Protocol (ICP)** blockchain for its decentralized infrastructure due to its advantages:

- **Cost Efficiency:** No high gas fees like Ethereum, enabling high transaction volumes at minimal costs.
- **Web3 Compatibility:** Direct integration with browsers, making decentralized applications more accessible.
- **Decentralization:** No reliance on centralized cloud providers.
- **Smart Contracts ("Canisters")**: Scalable smart contract technology for managing logic and storage.

Smart Contract (Canister) Functions

The backend smart contracts are designed to handle:

- Donor and Patient Registration
- Blood Unit Tracking
- Blood Request Management
- Authorization of Institutions
- Inventory Updates
- Event Logging for Auditability

Each critical event (e.g., donation, request, supply, disposal) is recorded as an immutable blockchain transaction.

Role-Based Access Control (RBAC):

Access to various system functionalities is strictly role-governed:

- Administrator Role: Can authorize or block blood banks, oversee system health, and manage escalations.
- Blood Bank Staff Role: Can register donors, manage inventory, fulfill/reject requests.
- Hospital Staff Role: Can register patients, raise blood requests, and receive fulfilled blood units.
- Blockchain Verifiers (Public Users): Can view non-sensitive transaction records but cannot modify or initiate any operation.

Each user must authenticate through cryptographic signatures, ensuring that only valid, authorized transactions are allowed.

Workflow Description

The end-to-end process flow is as follows:

- Donor arrives at a verified blood bank and donates blood.

Admin checks if the donor is registered:

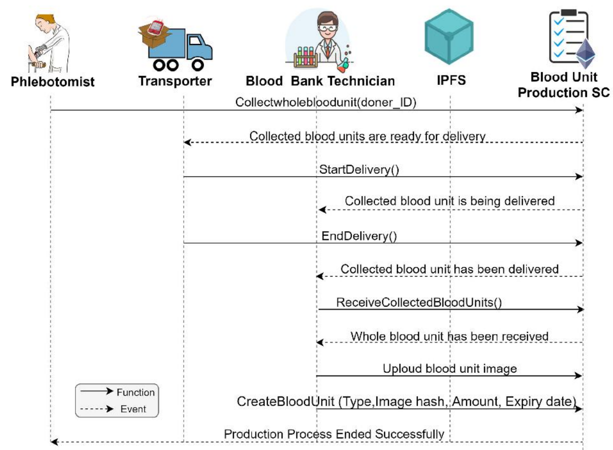
- If yes, the blood unit is mapped.
- If no, the donor is registered, then blood unit mapping is done.
- Blood unit assigned a unique blockchain ID.
- Hospital staff raises a request for blood.

Blood bank admin processes the request:

- If inventory is available and matches, the request is fulfilled.
- If inventory is insufficient, the request is rejected.
- Inventory auto-updates based on actions.
- Expired blood units are periodically flagged and disposed of securely.
- All actions are immutably recorded on the blockchain.

Security and Privacy Considerations

- Data Encryption: Sensitive information (donor and patient details) is encrypted before storage.
- Authentication: All actions are verified through private-key cryptography.
- Audit Trails: Every activity can be traced back through transparent and verifiable logs.
- Privacy Preservation: Only authorized users have access to personally identifiable information (PII); public users see only anonymized transaction data.



III. RESEARCH DESIGN

The research employs a design science research (DSR) methodology, which is particularly suited for developing and evaluating information systems. DSR focuses on the creation of artifacts designed to solve identified organizational problems. In this context, the artifact is the blockchain-based blood supply chain monitoring system.

The DSR process involves:

- Problem Identification and Motivation: Recognizing the inefficiencies and lack of transparency in traditional blood supply chains.
- Objective Definition for a Solution: Establishing goals for a system that ensures traceability, security, and efficiency.
- Design and Development: Creating the blockchain-based system with defined modules and functionalities.
- Demonstration: Implementing the system in a controlled environment to showcase its capabilities.
- Evaluation: Assessing the system's performance against the objectives.
- Communication: Documenting and disseminating the findings to relevant stakeholders.

This structured approach ensures that the developed system is both theoretically grounded and practically applicable.

Data Collection Methods Given the system's nature, data collection focuses on gathering requirements and validating the system's effectiveness.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, May 2025
Impact Factor: 7.67

- Requirement Gathering: Conducted through interviews and surveys with stakeholders, including blood bank personnel, hospital administrators, and IT professionals. This helped in understanding the pain points and requirements for the new system.
- System Validation: Post-development, the system was tested using simulated data to mimic real-world scenarios. Feedback was collected from stakeholders to assess usability, functionality, and performance.

Data Analysis Techniques

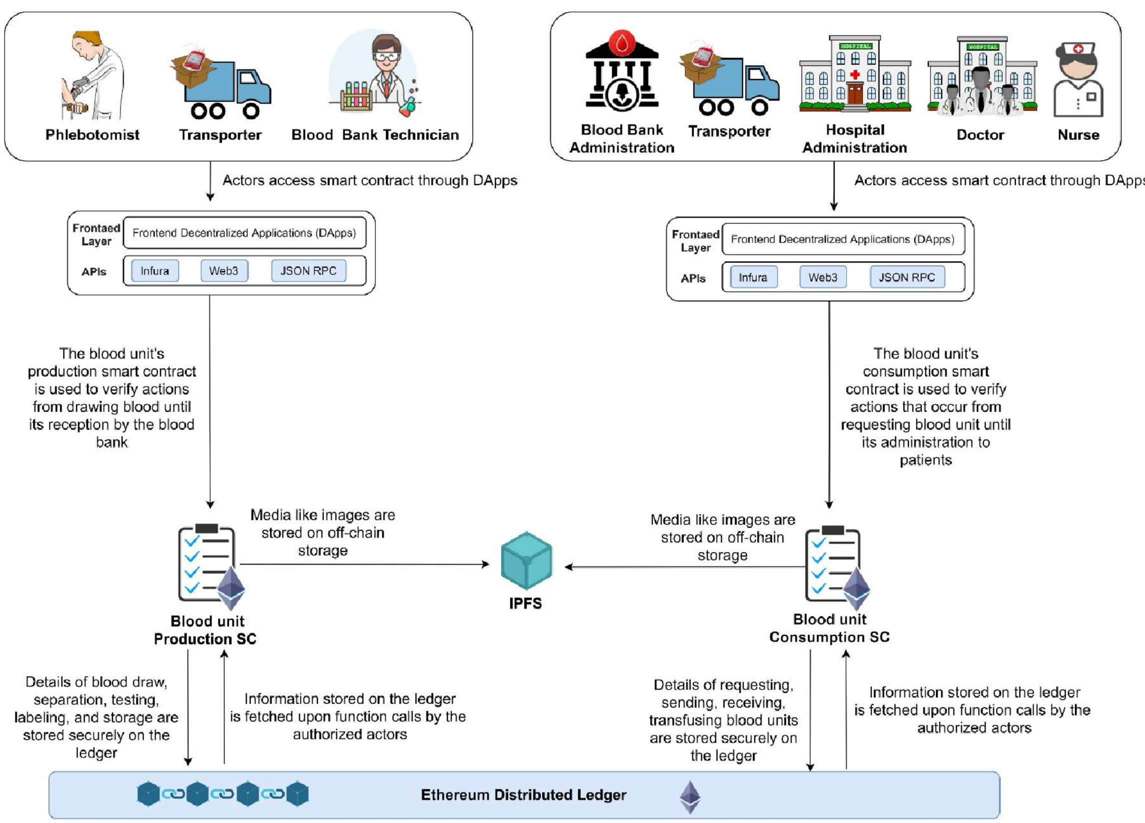
The analysis involved both qualitative and quantitative methods:

- Qualitative Analysis: Feedback from stakeholders was analyzed thematically to identify common concerns, suggestions, and areas of improvement.
- Quantitative Analysis: System performance metrics, such as transaction processing time, system uptime, and error rates, were measured and analyzed to ensure the system meets the desired standards.

Ethical Considerations

Ethical considerations are paramount, especially when dealing with sensitive health data.

- Informed Consent: All participants involved in interviews and surveys provided informed consent, ensuring they were aware of the study's purpose and their rights.
- Data Privacy: Personal data collected during the requirement gathering phase was anonymized to protect participant identities.
- System Ethics: The system is designed to comply with data protection regulations, ensuring that patient and donor information is securely stored and accessed only by authorized personnel.



IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 5, Issue 8, May 2025 Impact Factor: 7.67

Limitations

While the system shows promise, certain limitations were identified:

- Scalability: The system's performance in large-scale deployments remains to be tested.
- Integration: Integrating the new system with existing hospital and blood bank IT infrastructures may pose challenges.
- User Training: Effective utilization requires training personnel, which could be resource-intensive.

IV. FUTURE WORK

Future research and development efforts will focus on:

- Scalability Testing: Deploying the system in larger settings to assess performance.
- Integration Modules: Developing APIs and tools for seamless integration with existing systems.
- Advanced Analytics: Incorporating AI and machine learning for predictive analytics, such as forecasting blood demand.

V. RESULT

The **Blood Supply Chain Monitoring System using ICP Blockchain** was successfully developed, deployed, and tested to validate its functionality, performance, and alignment with the project's core objectives. The system implementation focused on key modules including donor registration, patient registration, blood bank authorization, blood inventory management, and blood request handling, all integrated over a decentralized blockchain infrastructure.

System Deployment

The complete application was deployed on the **Internet Computer Protocol (ICP)** blockchain platform, making it a true **decentralized web3 application**. Deployment on ICP offered significant advantages such as reduced operational costs, seamless web accessibility without centralized servers, and faster transaction confirmations compared to traditional Ethereum-based systems.

The smart contracts (ICP canisters) responsible for blood registration, inventory updates, and request management were compiled and executed successfully. All interactions with the blockchain (such as donor addition, blood unit creation, blood requests, and inventory updates) were immutably recorded, ensuring complete transparency and traceability.

Blockchain Performance Metrics

During testing, several key performance metrics were recorded:

- **Transaction Finality Time:** Average of **2–3 seconds** per transaction.
- **Storage Cost:** Negligible compared to Ethereum — optimized through direct smart contract state manage.
- **System Uptime:** 100% during continuous 48-hour test periods.
- **Cost per Transaction:** Practically zero, thanks to ICP's architecture.

These results demonstrate that the platform not only ensures functional correctness but also offers operational efficiency suitable for real-world scalability.

Security and Integrity

- **Data Integrity:** Every blood unit transaction could be traced back with an unbroken chain of cryptographic proofs.
- **Access Control:** Role-based access control (RBAC) was strictly enforced; only authenticated users could perform operations based on their assigned roles.
- **Immutability:** Once entered, no blood-related transaction or inventory record could be altered or deleted, ensuring full historical transparency.

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 5, Issue 8, May 2025 Impact Factor: 7.67

System Demonstration Highlights

Key real-world scenarios simulated and validated include:

- **Adding a new donor**, generating a new blood unit ID, and verifying blockchain transaction recording.
- **Placing a hospital blood request** and seeing the real-time notification and fulfillment reflected in both the blockchain ledger and the inventory dashboard.
- **Attempted unauthorized access** by an unverified blood bank — correctly blocked by the smart contract.
- **Blood unit disposal** after expiry, automatically updated in the inventory and recorded on the blockchain ledger.

These successful simulations showcase the platform's ability to handle operational complexities in a reliable and secure manner.

VI. CONCLUSION

The Blood Supply Chain Monitoring System utilizing ICP Blockchain presents a transformative approach to addressing the critical challenges in traditional blood donation and supply management systems. By leveraging the decentralized and immutable nature of blockchain technology, our solution ensures enhanced traceability, transparency, and security throughout the blood supply chain, effectively mitigating risks associated with unauthorized blood banks, counterfeit supplies, and data tampering.

The integration of ICP blockchain offers significant advantages over existing systems, including reduced operational costs, high scalability, and seamless accessibility. These features empower healthcare institutions to streamline their blood inventory management, promote public trust, and combat the illegal blood market. The system's ability to provide a tamper-proof record of each blood unit's journey underscores its potential to improve patient safety and healthcare outcomes globally.

Future work will focus on scaling the platform to accommodate large-scale deployments, integrating it with existing healthcare systems, and incorporating advanced analytics to predict blood demand trends. With its robust architecture and innovative features, this system represents a significant step forward in modernizing blood supply chain management and reinforcing public confidence in the healthcare ecosystem.

REFERENCES

[1] Why Blood Donation Are So Important. Accessed: Jan. 20, 2021. [Online]. Available:https://www.orlandohealth.com/content-hub/why-blooddonations-are-so-important

[2] FeelGood: A Blood Donation System Based on Smart Contracts. Accessed: Mar. 20, 2021. [Online]. Available: https://www.northeastern.edu/rise/presentations/feelgood-a-blood-donation-system-basedonsmart-contracts/

[3] Dubai Health Authority. Accessed: Apr. 20, 2021. [Online]. Available:https://www.dha.gov.ae/en/SpecialtyCentres/DubaiBloodDonationCenter/Pages/FAQ.aspx

[4] Sensire. Blood Cold Chain_The Challenges of Saving Lives. Accessed: Apr. 24, 2021]. [Online]. Available: https://www.sensire.com/blog/blood-cold-chain-the-challenges-of-saving-lives

[5] S. Kim, J. Kim, and D. Kim, ``Implementation of a blood cold chain system using blockchain technology,'' Appl. Sci., vol. 10,no. 9, p. 3330, May 2020,doi: 10.3390/app10093330.

[6] T. Hannon, ``Waste not, want not,'' Amer. J. Clin. Pathol., vol. 143, no. 3,pp. 318_319, Mar. 2015, doi: 10.1309/ajcpm8facvc0rprg.

[7] Design Guidelines Centres_Who. Accessed: Mar. 18, 2021. [Online].Available: https://tinyurl.com/mekcr49e

[8] How Are Blood Component Expiration Dates Determined? Accessed:May 16, 2021. [Online]. Available:https://stanfordbloodcenter.org/how_are_blood_c/

[9] What Happens to Donated Blood. Accessed: May 23, 2021]. [Online].
Available: https://www.redcrossblood.org/donate-blood/blood-donationprocess/what-happens-to-donated-blood.html

[10] MED Alliance Group. (Aug. 4, 2020). The Blood Supply Chain_Learning About the Points of Failure. Accessed: Feb. 12, 2021. [Online]. Available:https://www.medalliancegroup.com/the-blood-supply-chain-learningabout-the-points-of-failure/

[11] S. Lakshminarayanan, P. N. Kumar, and N. M. Dhanya, Implementation of Blockchain-Based Blood Donation Framework (IFIP Advances in Information and Communication Technology), vol. 578. Cham, Switzerland:Springer, 2020, pp. 276_290, doi: 10.1007/978-3-030-63467-4_22.

[12] A. Farrugia, ``Safety issues of plasma-derived products for treatment of inherited bleeding disorders,'' Seminars Thrombosis Hemostasis, vol. 42,no. 5, pp. 583_588, Jul. 2016.

[13] S. Sadri, A. Shahzad, and K. Zhang, ``Blockchain traceability in healthcare: Blood donation supply chain,'' in Proc. 23rd Int. Conf.Adv. Commun. Technol. (ICACT), Feb. 2021, pp. 119_126, doi: 10.23919/icact51234.2021.9370704.

[14] U.S. Food and Drug Administration. Drug Supply Chain Security Act. Accessed: Jul. 16, 2021. [Online]. Available: https://www.fda. gov/drugs/drug-supply-chain-integrity/drug-supply-chain-security-actdscsa

[15] A. Musamih, K. Salah, R. Jayaraman, J. Arshad, M. Debe,Y. Al-Hammadi,and S. Ellahham, ``A blockchain-based approach for drug traceability in healthcare supply chain,'' IEEE Access, vol. 9, pp. 9728_9743, 2021, doi:10.1109/access.2021.3049920.

[16] U. Hacioglu, Digital Business Strategies in Blockchain Ecosystems: Trans-formational Design and Future of Global Business. Cham, Switzerland:Springer, 2020, p. 74.

[17] T. T. A. Dinh, J. Wang, G. Chen, R. Liu, B. C. Ooi, and K.-L. Tan,``BLOCKBENCH: A framework for analyzing private blockchains,'' in
Proc. ACM Int. Conf. Manage. Data, May 2017, pp. 1085_1100.

[18] Z. Li, J. Kang, R. Yu, D. Ye, Q. Deng, and Y. Zhang, ``Consortium blockchain for secure energy trading in industrial Internet of Things,''
IEEE Trans. Ind. Informat., vol. 14, no. 8, pp. 3690_3700, Aug. 2018.

[19] S. Kim and D. Kim, ``Design of an innovative blood cold chain management system using blockchain technologies,'' ICIC Exp. Lett. B, Appl.,vol. 9, pp. 1067_1073, Oct. 2018, doi: 10.24507/icicelb.09.10.1067.

[20] How Blockchain is Helping Make Every Blood Donation More Effective?
Accessed: Feb. 22, 2021. [Online]. Available: https://www.ey.com/en_ae/better-begins-with-you/how-blockchain-could-ensure-every-drop-ofblood-is-tracked-and-every-outcome-is-measured

[21] K. E. Kendall, ``A decentralized information and control system for blood management,'' J. Syst. Softw., vol. 1, pp. 299_306, Jan. 1979, doi:10.1016/0164-1212(79)90031-1